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LHC Interaction Region Quadrupole Cryostat
Heat Exchanger Feedbox Module Specification

Fermilab Specification: 5520-ES-364246

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1.0 Scope.

1.1 This specification defines the requirements for a cryogenic vessel to be delivered to Fermilab for subsequent use at CERN in Geneva, Switzerland. This feedbox will be used to test the performance of a 1.8K heat exchanger identical to one proposed for incorporation in cryostats being developed by Fermilab for installation in the Large Hadron Collider (LHC) interaction regions at CERN.

The feedbox must be designed and constructed to comply with the requirements of the latest version of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code and must be code-stamped to verify that compliance.

The feedbox assembly is shown in Fermilab drawing 5520-ME-364234.

2.0 Feedbox module description.

2.1 The feedbox being fabricated connects at one end of four identical cryogenic vessels assembled in series into a string approximately 30 meters long. The other end of the string will be attached to a turnaround module. Neither the turnaround nor the main cryogenic modules are subjects of this specification.

2.2 The feedbox includes an external vacuum vessel, a thermal shield cooled by helium vapor, a counter-flow heat exchanger, a phase separator, four control valves, four safety valves, and other helium piping. Support structures for the phase separator, counter-flow heat exchanger and shields and blankets of multi-layer insulation serve to limit heat conduction and radiation from the surrounding environment to the helium systems. Temperature, pressure, and liquid level instrumentation serve to support the testing required to verify the performance of the heat exchanger.

2.3 Length and diameter dimensions shown on 5520-ME-364234 and all constituent subassembly drawings must be maintained. Materials, tube and pipe wall thicknesses, flange thicknesses, and weld dimensions must be verified by the module manufacturer to ensure compliance with pressure vessel code requirements.

3.0 Outer vacuum vessel design requirements.

3.1 The vacuum vessel, flanges, stiffening structures, instrumentation tubes, and vacuum relief assemblies shall be fabricated from type 304 stainless steel. Dimensions are referenced on drawing 5520-MD-364077 and 5520-ME-364177.

3.2 Although the outer vacuum vessel is not required to be a code compliant vessel, it must be designed and manufactured to the rules and recommended practices of the latest version of the ASME Code, Section VIII, Division 1 for vacuum vessels.

3.3 The outer vessel (both vertical and horizontal part) shall be capable of withstanding full internal vacuum with one atmosphere pressure on the outside with a safety factor of two.

3.4 Copies of any and all material certifications and material test results must be supplied with all assemblies.

4.0 Low temperature shield design requirements.

4.1 The low temperature shield shall be fabricated from aluminum sheet and 304L or 316L stainless steel tube. Dimensions are referenced on drawing 5520-MD-364276, 5520-MD-364343, 5520-MD-364346, 5520-MD-364349, 5520-MD-364354, and 5520-MD-364386. Refer to section 5.0 for additional requirements on the shield tube assemblies.

4.2 All supports for the low temperature shield pipes must allow free expansion and contraction where necessary.

4.3 The low temperature shield shall be insulated using 32 layer-pairs of multi-layer insulation (MLI) consisting of alternating layers of reflective mylar and spacer material. Dimensions and materials are referenced on drawings 5520-MD-364277, 5520-MD-364399, 5520-MC-364361, and 5520-MC-364380.

4.4 The phase separator, counter-flow heat exchanger and all internal pipes shall be insulated using 16 layer-pairs of multi-layer insulation (MLI) consisting of alternating layers of reflective mylar and spacer material.

4.5 Copies of any and all material certifications and material test results must be supplied with all assemblies.

5.0 Internal piping design requirements.

5.1 All internal piping material shall be 304L or 316L series stainless steel and shall be formed from continuous lengths of pipe or tube to the maximum extent practical. Joints shall be welded in a manner consistent with applicable codes. Dimensions are referenced on drawing 5520-ME-364218, and all constituent subassembly drawings.

5.2 All supports for the internal pipes must allow free expansion and contraction where necessary.

5.3 The following table summarizes the operating requirements for the internal piping.

Description	Fluid	Temperature Range	Internal Pressure Range	External Pressure Range
Phase separator	LHe	300K to 4.5K	Vacuum to 20 Bars	Vacuum to 1 Bars
LHe supply	LHe	300K to 1.8K	Vacuum to 20 Bars	Vacuum to 1 Bars
Cool down supply	LHe	300K to 4.5K	Vacuum to 20 Bars	Vacuum to 1 Bars
Cooldown return	LHe and GHe	300K to 1.8K	Vacuum to 20 Bars	Vacuum to 1 Bars
Low temperature shield	LHe and GHe	300K to 4.5K	Vacuum to 20 Bars	Vacuum to 1 Bars
Heat exchanger internal pipe	LHe and GHe	300K to 1.8K	Vacuum to 20 Bars	Vacuum to 1 Bars
All other internnal pipes	LHe and GHe	300K to 1.8K	Vacuum to 20 Bars	Vacuum to 1 Bars

6.0 Bellows.

6.1 All of the internal piping and the external vacuum vessel will be joined to adjacent modules using stainless steel bellows. All bellows will be supplied by Fermilab to CERN and are not part of this fabrication or specification.

7.0 Instrumentation.

7.1 Instrumentation is provided to measure the temperature, pressure, and liquid level of all of the cryostat systems at operating conditions. These devices, their associated wiring, and external connectors are fragile and prone to failure if mishandled, improperly protected from heat or high electrical currents, especially during welding. Care must be exercised at all times and sufficient checks must be incorporated into the assembly processes to ensure the operational integrity of these devices.

7.2 All instrumentation will be supplied by Fermilab and are not part of this specification.

8.0 Safety relief devices.

8.1 All safety relief devices will be supplied by Fermilab and are not part of this specification.

9.0 Testing and documentation.

9.1 Piping shall be pneumatically testing at 125% of the maximum allowable working pressure (MAWP). All joints, including safety device inlet connections, shall be soap bubble checked for leakage at the test pressure.

9.2 The following tests shall be performed with the insulating vacuum connected to a leak detector with a minimum sensitivity of $2x10^{-9}$ torr-liter/sec of helium.

9.2.1 All joints on the outside of the vacuum vessel shall be sprayed with helium with no detectable leak.

9.2.2 The internal helium piping systems shall be pneumatically pressurized to 125% of their MAWP with helium with no detectable leak.

9.3 The manufacturer shall furnish all code UA-1 forms and certificates of mass spectrometer and piping tests.

10.0 On-site inspections by Fermilab.

10.1 Fermilab reserves the right to make on-site inspections of the module components and assembly during manufacturing. In particular, Fermilab would like to inspect the internal piping prior to wrapping with MLI and the instrumentation assemblies prior to welding them in place.

11.0 Fermilab supplied material.

11.1 Fermilab will supply the calibrated thermometers mounted on circuit boards with wires attached, the liquid level indicators, the heaters and all room temperature electrical connectors for connection to the instrumentation.

11.2 Fermilab will supply CVI vacuum pumpouts for welding to the vacuum vessel assembly and control valves.

11.3 Fermilab will supply JTX heat exchanger as a unit which has the drawing number 1650-ME-250550.

12.0 Cleaning and packaging.

12.1 All module components must be free of grease, residue, dirt, and chips and packaged such as to ensure delivery in a clean condition.

12.2 The vendor is responsible for shipment of the module from its point of manufacture to Fermilab. Fermilab in turn will handle shipping to CERN. However, the vendor shall provide a shipping container for the module compatible with the need to ship from their facility to Fermilab by truck and/or rail and from Fermilab to CERN by ocean going transport.

13.0 Warranty.

13.1 The manufacturer will warrant all materials and workmanship for a period of 18 months from shipment. The only exceptions will be items supplied by Fermilab.